A New Attenuation Relationship for Velocity Response Spectra at the surface

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We integrated the attenuation relationships proposed by Matsu’ura et al.(2011) to be able to predict the velocity response spectrum for an arbitrary source at an arbitrary site in wide range of distance and period. We divided data into three groups of source types as follows: inter-plate, intra-plate, and very shallow earthquakes. In order to determine parameters at once, we expand each parameter by cubic B-splines, as Yabuki and Matsu’ura(1992) did, and transform the problem to be solved in a linear inversion. We also introduce the upper limit of the plate depth at a site to be considered, such as 250km for PAC slab, by comparing AICs for various limit depth and various types of formulae.

Sv_{ij} is the velocity spectrum at the *i*-th site of hypocentral distance $DELTA_{ij}$, where the depth of subducting slab is dep_i, due to the *j*-th earthquake of Mw_j with the residual of e_{ij}. For inter-, and intra-plate earthquakes, the relation is the form of Eq. (1), while for very shallow earthquakes, Eq. (2) is the form. Here, t is the period.

$$\log Sv_{ij}(Mw_j, DELTA_{ij}, dep_i, t)= Mw_j\ A_w(t) +A_c(t)-Beta(t)\log(DELTA_{ij})-d(t)dep_i+e_{ij}(t) \quad \text{Eq.(1)}$$

$$\log Sv_{ij}(Mw_j, DELTA_{ij}, t)= Mw_j\ A_w(t)+A_c(t)-b(t)DELTA_{ij}-Beta(t)\log(DELTA_{ij})+e_{ij}(t) \quad \text{Eq.(2)}$$

In Eq. (1), the term with the coefficient *b(t),* which is always contained in conventional engineering formulae of the attenuation relationship for response spectra, is omitted. We found: 1) the term with *b(t)* in Eq. (2) works to represent the plateau shape of spectra in very small *DELTA*, especially in short period. 2) The coefficient *Beta(t),* which we introduced, works well alone to fit data of inter- and intra-plate earthquakes without *b(t)*, since data with very small *DELTA* are rare for those types of earthquakes in Japan. 3) Even in Eq. (2), *b(t)* is nearly zero for periods over about 2sec. 4) The coefficient *d(t)* in Eq. (1), which is usually believed to represent the effect of High-Q and High-V subducting slab, is even effective to represent the effects from large scale of geological structure differences in Japanese crust, such as rather low Q features of western part of the northeastern Japan, and the attenuation discrepancy between the east and west of the Hida mountains.

The site response $e_{ij}(t)$ *is almost independent of the source types,* Mw_j*, and* $DELTA_{ij}$*, i.e. nearly equal to* $e_i(t)$*.* It was empirically confirmed that $e_i(t)$ can be replaced by H/V spectral ratio obtained from the observed micro-tremors. Eqs. (1) and (2) can be used to calculate velocity spectra at any site for any expected sources without knowing AVS30 or geotechnical classification of that site.

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Keywords: Attenuation relationships of Velocity Response Spectra, Upper limit of the effective plate depth at a site, Selection by AIC, linear inversion method with cubic B-spline expansion

